REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	JUNE 2004	TECHNICAL REPORT

4. TITLE AND SUBTITLE
RELIABILITY OF MEDIAN NERVE SOMATOSENSORY EVOKED POTENTIALS USING THE NICOLET PATHFINDER II

5. FUNDING NUMBERS

6. AUTHOR(S)
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8. PERFORMING ORGANIZATION REPORT NUMBER
T04-07

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Medical Research and Materiel Commad
Fort Detrick, MD 21702-5007

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
This report provides normative values for median nerve somatosensory evoked potential (SEP) waveform latencies and amplitudes, and an assessment of the reliability for these SEPs for the USARIEM laboratory. Median nerve SEPs were obtained using a Nicolet Pathfinder II (Nicolet Biomedical Instruments, Madison, WI). Assessments were done with volunteers in a rested, relaxed state, on three days with two trials per day. Normative latency measurements (mean ± standard deviation (SD)), Intraclass R, and the coefficient of variation (CV) of each measure were for N9 (9.67 ± 0.80 msec, R = 0.92, CV = 3.7 ± 3.2%), N13 (12.81 ± 0.87 msec, R = 0.85, CV = 5.3 ± 2.9%), N19/N20 (18.43 ± 1.18 msec, R = 0.93, CV = 18.5 ± 4.8%), and P22 (22.31 ± 1.39 msec, R = 0.92, CV = 3.5 ± 2.2%). For amplitude assessments the following measures were N9 (1.20 ± 0.61 μV, R = 0.86, CV = 53.6 ± 29.9%), N13 (1.15 ± 0.42 μV, R = 0.72, CV = 47.4 ± 19.9%), N19/N20 (2.23 ± 0.75 μV, R = 0.76, CV = 36.1 ± 13.8%), and P22 (2.08 ± 0.86 μV, R = 0.88, CV = 40.7 ± 33.2%). Latency measures were determined to be reliable using Intraclass R and CV, with small variations over days. Amplitude measures were not reliable with Intraclass R's < 0.90 and CVs that exceeded 10%. Establishment of laboratory normative measurement allows researchers at USARIEM to better evaluate changes observed during conditions of altered CNS function. These normative values are consistent with those obtained from other laboratories. Since these data demonstrate that the techniques employed in this study produce valid and reliable measurements, future studies using median nerve SEPs at USARIEM should now use the values published in this report as the normative values for comparative purposes.

14. SUBJECT TERMS
Somatosensory Evoked Potentials, Median Nerve, Reliability, Normative Values, Nervous System, Muscle Electrical Stimulation, Neurological Function, Brain Response, Central Nervous System

15. NUMBER OF PAGES
23

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
U	U	U	U

USARIEM TECHNICAL REPORT T04-07

RELIABILITY OF MEDIAN NERVE SOMATOSENSORY EVOKED POTENTIALS USING THE NICOLET PATHFINDER II

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ACKNOWLEDGEMENTS

We would like to thank Dr. Margaret Kolka for her review of this report and Julio Gonzalez and Phil Niro for their assistance in preparing the figures. We appreciate the commitment of all the volunteers who participated in this study and the medical staff who oversaw the health of these volunteers while they were in the study.

EXECUTIVE SUMMARY

Measurement of somatosensory evoked potentials (SEPs) is a valuable tool for assessing the functional integrity and changes due to various treatments that affect the central and peripheral nervous system. This report provides normative values for median nerve SEP waveform latencies and amplitudes, and an assessment of the reliability for these SEPs for the USARIEM laboratory. Median nerve SEP latencies have been reported to be one of the most reliable SEP measurements. Median nerve SEPs were obtained using a Nicolet Pathfinder II (Nicolet Biomedical Instruments, Madison, WI). Assessments were done with volunteers in a rested, relaxed state, on three days with two trials per day. Normative latency measurements (mean ± standard deviation (SD)) in msec, Intraclass *R*, and the coefficient of variation (CV) of each measure were:

Peak Latency N9	**Peak Latency N13**	**Peak Latency N19/20**	**Peak Latency P22**
9.67 ± 0.80	12.81 ± 0.87	18.43 ± 1.18	22.31 ± 1.39
R = 0.92	*R* = 0.85	*R* = 0.93	*R* = 0.92
CV = 3.7 ± 3.2%	CV = 5.3 ± 2.9%	CV = 18.5 ± 4.8%	CV = 3.5 ± 2.2%

Normative amplitude measurements (mean ± SD) in μV, Intraclass *R*, and the CV of each measure were:

Peak Latency N9	**Peak Latency N13**	**Peak Latency N19/20**	**Peak Latency N19/N20-P22**
1.20 ± 0.61	1.15 ± 0.42	2.23 ± 0.75	2.08 ± 0.86
R = 0.77	*R* = 0.72	*R* = 0.76	*R* = 0.88
CV = 53.6 ± 29.9%	CV = 47.4 ± 19.9%	CV = 36.1 ± 13.8%	CV = 40.7± 33.2%

Latency measures were determined to be reliable using Intraclass *R* and CV, with small variations over days. Amplitude measures were not reliable with Intraclass *R*'s < 0.90 and CVs that exceeded 10%. Standing height was shown to be correlated significantly with SEP latency measurements because it takes longer for the signal to travel the length of the nerves in longer limbed individuals. Therefore, standing height should be considered when assessing the effects of experimental treatments or potential neurological disorders. There was no effect of age on SEPs within the range of volunteers tested (18 to 33 years). Establishment of laboratory normative measurement allows researchers at USARIEM to better evaluate changes observed during conditions of altered CNS function, such as might be produced by fatigue, hydration status, various medications, etc. These normative values are consistent with those obtained from other laboratories published in the literature. Since these data demonstrate that the techniques employed in this study produce valid and reliable measurements, future studies using median nerve SEPs at USARIEM should now use the values published in this report as the normative values for comparative purposes.

INTRODUCTION

Evoked potentials (EPs) are electrical signals generated by the central nervous system (CNS) in response to a specific type of auditory, visual, or somatosensory stimulus (5). These electrical potentials are much smaller than electroencephalographic (EEG) records, which record all brain electrical activity, and as such, they are embedded within EEGs. The use of signal averaging systems such as the Nicolet Pathfinder II (Nicolet Biomedical Inc., Madison, WI) allows for EPs to be isolated from the background EEG. This method reduces the amplitude of the EEG component that is not related to the stimulus and thereby enhances the features of the response that is time-locked to the stimulus (23).

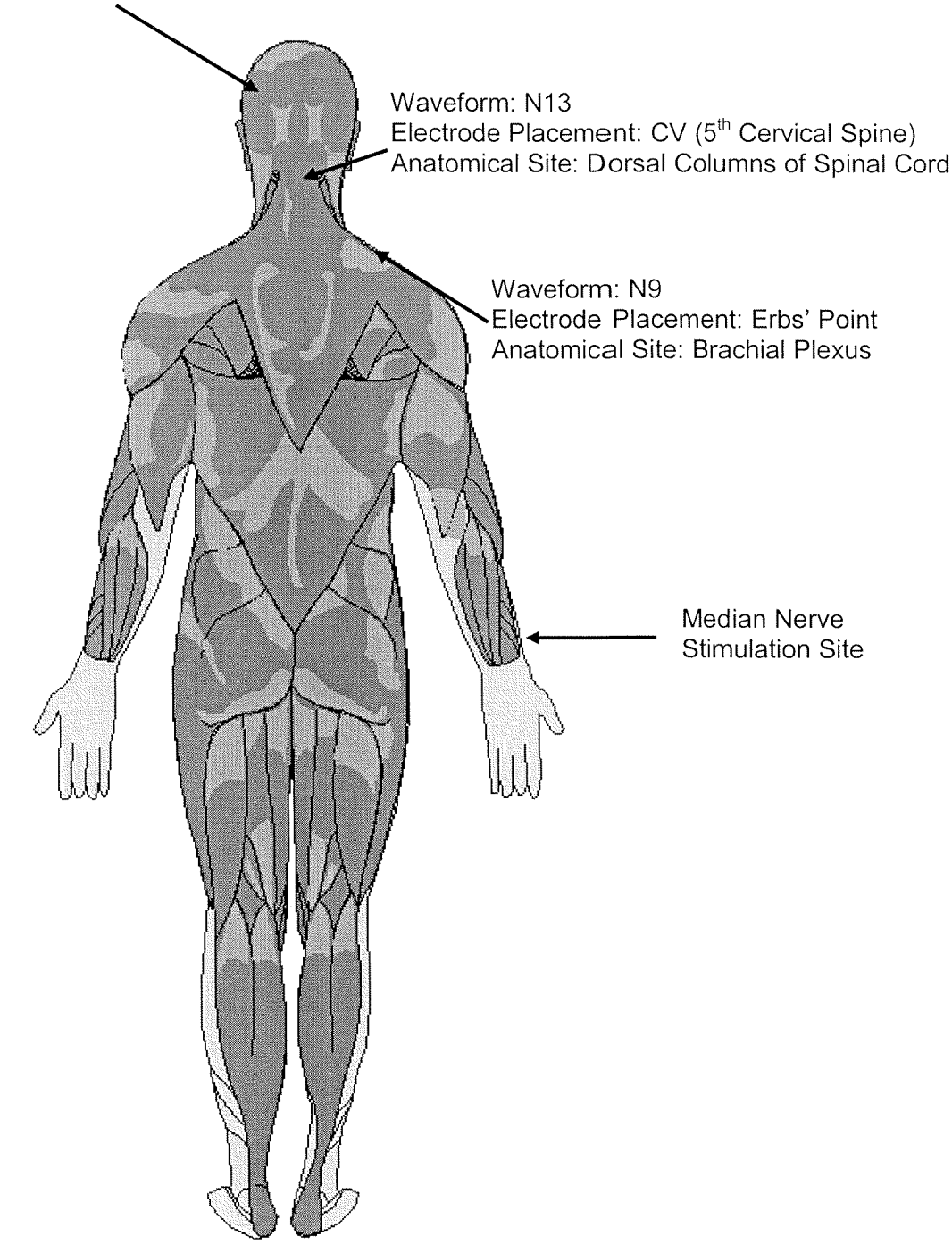
Somatosensory evoked potentials (SEPs) are obtained by placing receiving electrodes (to measure electrical activity of the brain and spinal cord) on specific anatomical locations to calculate responsiveness of the CNS to an applied electrical stimulus. The CNS EPs can originate in the spinal cord, brainstem, or cerebral areas of the brain (10). One of the most often used SEPs is obtained by stimulating the median nerve. Median nerve SEPs have a high signal-to-noise ratio and reliable latency responses, which allows for their use in clinical evaluations of CNS integrity (23).

For the median nerve SEP, there are several commonly labeled peak latencies (N9, N13, N19 or N20, and P22). With electrode montages that are commonly used for SEPs, convention has that upward deflections in the electrical potentials are regarded as negative and downward defections are regarded as positive (20). The general time from stimulus to peak deflection is referred to as the expected latency. For example, N9 means that an expected negative (up) deflection should occur somewhere around 9 msec after the stimulus to the nerve as been applied.

While the exact generator of the various latency peak potentials is not known, there are some commonly accepted sites (see Figure 1). N9 peak is due to excitation of peripheral nerve fibers between the axilla and the spinal cord (23). N13 is located in the spinal cord probably near the dorsal columns and in the nucleus cuneatus of the dorsal columns. Other research has cited that N13 may also be related to activity in the dorsal horn of the spinal cord or the dorsal column nuclei and/or the medial lemniscus (7). N19/N20 is thought to originate in the primary sensory cortex (23) or the parietal cortex region of the brain contralateral to the stimulated arm (23), and there is also considerable evidence that the thalamus is involved (7). Chiappa (5) states that the deflection occurring around 19 msec has been labeled both N19 and N20 in the literature. We use the notation of N19/N20 to designate this waveform and we make comparisons to other studies that use either N19 (e.g., Chiappa (5)) or N20 (e.g., Spehlman (23)). It is generally agreed upon that P22 is also generated in the parietal sensory cortex (5).

It has been suggested by the leading researchers in the field that each laboratory establish its own normative database for each of the EP measures assessed (1, 5, 10, 23). Data from other laboratories may be initially used as a reference standard.

Figure 1. Body schematic showing waveforms and their associated anatomical sites.



However, once normative data from a laboratory has been established, that data should be used for all future studies conducted in that laboratory. To make comparisons with other laboratories, the normative values should replicate those of the reference laboratory. Spehlman (23) recommends that 95 percent of the volunteers tested in the new laboratory fall within the limits derived from the reference laboratory before the results should be considered replicated. As Romani et al. (21) state, "it is troublesome that there is a lack of reliability studies with EP data, while the need is great if comparison changes in latency or amplitude measures are to be obtained." The appropriate measure to assess reliability is an intraclass reliability analysis (13, 16, 17) which is rarely performed with regard to EP data (21). The purpose of this study was to a) to establish a normative median nerve SEP database for the USARIEM EP Laboratory and b) assess the reliability of the median nerve SEP.

METHODS

VOLUNTEERS

Thirteen men and eight women served as volunteers for this study. Volunteers were between the ages of 18 to 33 years, mean $\pm$ standard deviation (SD) age of 21.9 $\pm$ 3.4 years. Volunteers (n= 14; 12 men and 2 women) who had height and weight measurements taken were 169.8 $\pm$ 10.1 cm tall, range: 145.9 to 185.3 cm, and weighed 76.0 $\pm$ 14.4 kg, range: 50.2 to 99.0 kg. The Institute's Scientific and Human Use Committees approved the study. Prior to data collection all volunteers were briefed on the purpose, procedures, and known risks of the study and gave their written consent. All volunteers were without clinical evidence of nervous system diseases or injuries.

EXPERIMENTAL PROCEDURE

Silver-silver chloride disk electrodes were applied to the scalp at standard locations (C_3', CV, and on the Erb's points (left and right) on the neck (Figure 2). These electrode placements are those specified in the published protocol of Nicolet Biomedical Instruments (20) using standardized locations as specified in the 10-20 Electrode Placement System (15). Landmarks followed those specified by the American Electroencephalographic Society (3) and are described below:

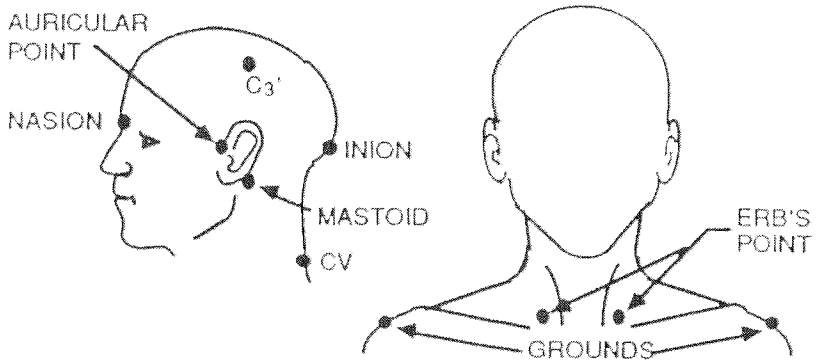
C_3' is determined by a series of measurements. C_z is midway between the nasion (anatomical point on the nose) and inion (anatomical point on the back of the head) on the midline of the scalp. The midline is halfway between the auricular points (where the ear meets the head). C_3 is 40% of the way from C_z to the left auricular point, and C_3' is 2 cm posterior to C_3.

CV is the fifth cervical spine electrode placed on the second smaller bump at the base of the head on the neck.

Erb's Points are located just above the collarbone and slightly to the left of the neck for the left Erb's Point and slightly to the right of the neck for the right Erb's Point.

Ground Electrode is located on the base of the shoulder.

Figure 2. Electrode placement on the body, schematic from Nicolet Pathfinder's User Guide (Nicolet Biomedical Instruments, 1987).



The following electrode montage (electrode placement and active to reference electrode alignments) was used and recorded on the following channels of the Nicolet Pathfinder II.

Channel 1: Erb's Point Left to Erb's Point Right. The N9 component (cervical potential).

Channel 2: Erb's Point Left to CV. The N13 (cervical potential) measured.

Channel 3: Erbs' Point Left to C_3'. Components measured N19/N20 and P22 (short latency brain potentials).

Electrode cites were pre-conditioned using Omni-Prep (D.O. Weaver and Co., Aurora, CO) or NuPrep (D.O. Weaver and Co., Aurora, CO). These are natural gum based solutions containing a natural abrasive, glycerine, sodium citrates and a preservative. Electrodes were attached with electrode pastes Medi-Trace EEG Sol (Graphic Controls Corp, Buffalo, NY) or TEN20 EEG Paste (D.O. Weaver and Co., Aurora, CO). Skin electrodes were secured with a mild adhesive tape (e.g., Hy-Tape; Patterson, NY). Scalp electrodes remained secure with the electrode paste in the hair. All electrode impedances were verified to be less than 5 kOhms and of about the same level. The appropriate leads were connected to a Nicolet remote plug-in board leading to the signal input of the Nicolet Pathfinder II signal averaging system.

To perform the stimulation procedure, the cathode was placed over the tendons of the palmaris longus and flexor carpi radialis muscles, 2 cm proximal to the most prominent wrist crease. The anode was located 3 cm distal to the cathode. A plate electrode over the palmer surface of the forearm was used as the ground electrode. To landmark the stimulation site, a stimulus rate of 2.1 stimuli per second was used and the stimulus intensity was progressively increased until a visually apparent twitch of the thumb occurred. If no twitch was obtained by 16 mA, the position of the stimulating probe was adjusted. During data collection the stimulation rate was increased to 8.1 stimuli per second with duration set at 100 μsec. Filter settings were set at 30 HZ (low bandpass), 60 HZ (notch filter) and 1.5 KHZ (high bandpass). A total of 500 individual EPs were averaged for each trial. Two trials per day for three days were obtained. During the procedure the volunteers sat in a reclined position in a phlebotomy chair with their eyes closed. The procedure was performed in an acoustically isolated room with dim lighting and volunteers were told to relax. Identification of the various peaks was performed using generally accepted criteria (11, 20) by an experienced EP technician. Waveform latencies and amplitudes were calculated using the Nicolet Pathfinder II's internal software (20).

DATA ANALYSIS

Reliability estimates deal with both stability and consistency of measures (16). Stability is a measure of resistance to influence from repeated testing and/or accuracy of application of the electrodes to their particular sites and can be assessed with a repeated measures analysis of variance (ANOVA). Consistency shows that the same factor is being measured on different occasions. Intraclass reliability is a technique that assesses consistency via ANOVA (13, 17). The method of using the mean square values to calculate the different sources of error are described by Lindquist (17) in detail. This technique is preferred over interclass Pearson product-moment correlation in its ability to distinguish the various sources of error within an observed score (16). Intraclass reliability (R) is expressed as follows:

$$R = \frac{\sigma^2 \text{ True Score}}{\sigma^2 \text{ True Score} + \sigma^2 \text{ Error Due to Trials} + \sigma^2 \text{ Error Due to Days}}$$

with σ^2 equal to the population variance (we used subject variance, i.e., SD^2) associated with the different ANOVA effects (e.g., days and trials).

A coefficient of variation (CV) was also calculated to determine the level of dispersion present for each waveform latency and amplitude across days and trials. The CV was calculated as the SD divided by the mean of each volunteers' measurements over all their trials on the three days multiplied by 100.

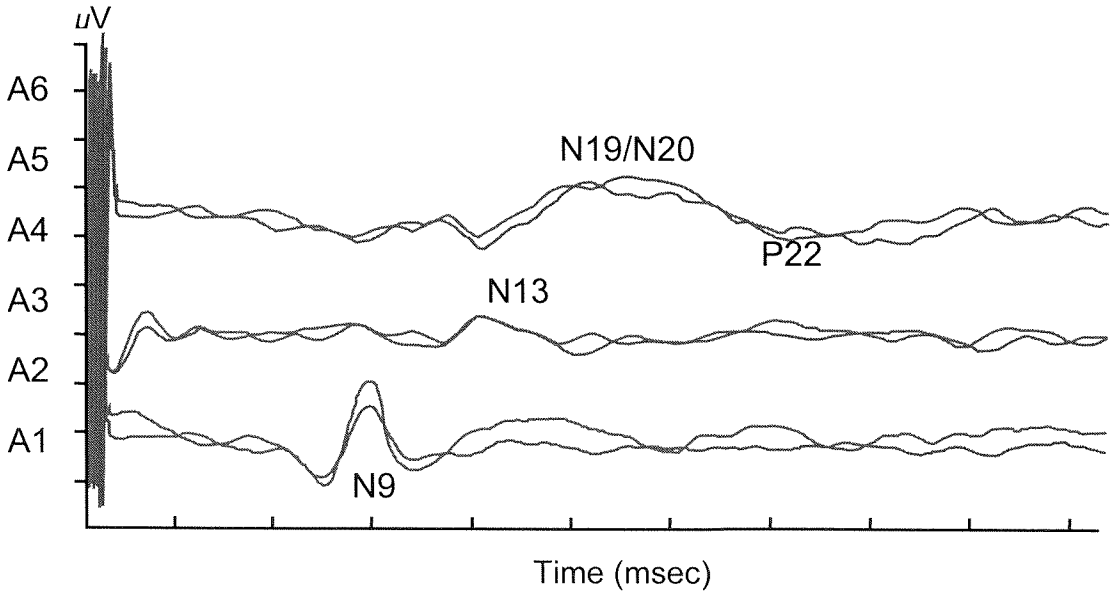
Pearson product-moment correlations were performed to obtain the relationship between age and height and SEP measurements. Gender effects were examined using ANOVA. Standing height measurements were only obtained on two women, therefore

use of standing height as a covariate in an analysis of covariance (ANCOVA) was not done.

RESULTS

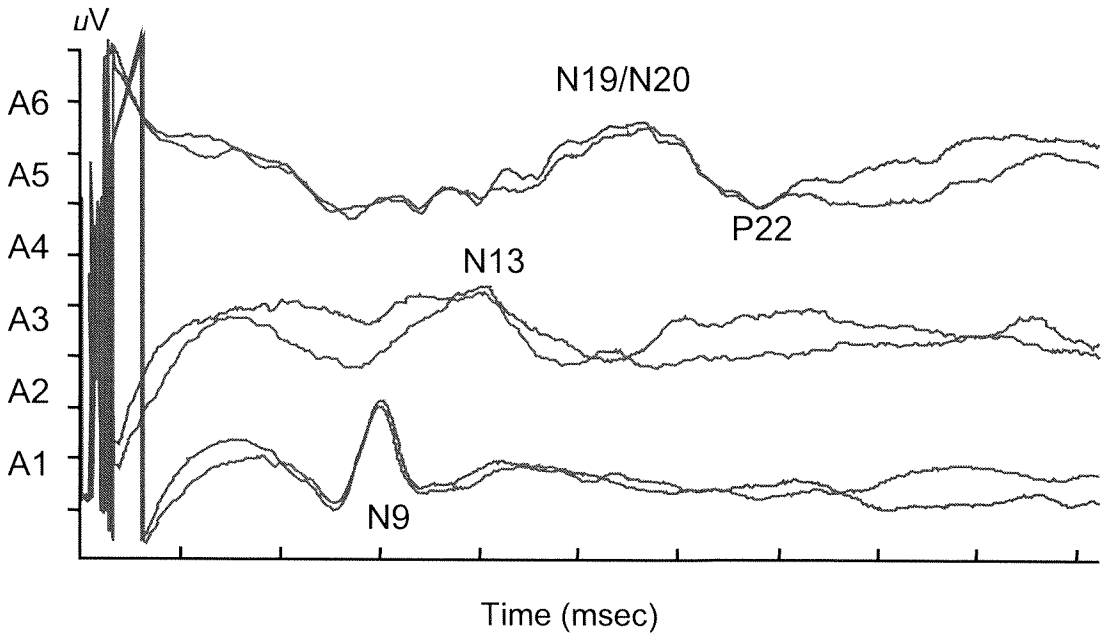
Figure 3 illustrates two sets of waveforms of a textbook (20) standard right arm median nerve SEP. Waveform latency components (N9, N13, N19/N20, and P22) are identified. Amplitudes are measured from base to the peak of the N9, N13, and N19/N20 latencies and from peak to peak for the N19/N20 to P22 latency. Figure 4 illustrates a clear, representative example of the reproducibility of the right median nerve SEP waveform of one volunteer (female) from this study. Rejected waves due to artifacts were less than 10% of stimuli administered. Of note is the reproducibility of two different trials for this SEP. No significant differences existed between waveforms.

Figure 3. Textbook example of two repeated median nerve somatosensory evoked potential recordings from Nicolet Pathfinder's User Guide (Nicolet Biomedical Instruments, 1987).



* Note: The amplitude in μV and the latencies in msec of the different waveforms are on different scales for the 3 channels x 2 trials (A1-A6), which is why the left and bottom axes have no absolute values associated with them.

Figure 4. Example of two repeated median nerve somatosensory evoked potential recordings from this study.



* Note: The amplitude in μV and the latencies in msec of the different waveforms are on different scales for the 3 channels x 2 trials (A1-A6), which is why the left and bottom axes have no absolute values associated with them.

Table 1 shows the means and SDs of all volunteers for the various latency measures. Intraclass reliabilities showing the consistency of measures ranged from R = 0.85 to 0.93. Stability of measures assessed by repeated measures ANOVA showed day effects were observed for N9, N13 and the N19/N20 waveforms with Day 2 having slightly longer latencies for all three waveforms compared to Days 1 and 3. A trial effect existed for the N19/N20 waveform with the second trial having a slightly longer latency than the first trial. The CVs were less than 6% for all latency measures except N19/N20 where it was approximately 18%.

Table 2 shows the means and SDs for all volunteers for the various amplitude measures. Intraclass reliabilities ranged from R = 0.72 to 0.88. A trial effect existed for the N13 amplitude with the second trial having greater amplitude than the first. CVs were between 40 and 55% for amplitudes.

Table 1. Latency measures (Mean ± SD) by day and trial with consistency (Intraclass *R*) and stability (ANOVA) of measures and the coefficient of variation.

N9 (msec)	**N13** (msec)
Day 1 Trial 1 9.43 ± 0.99	Day 1 Trial 1 13.23 ± 1.17
Day 1 Trial 2 9.63 ± 0.98	Day 1 Trial 2 13.10 ± 1.44
Day 2 Trial 1 9.88 ± 0.83	Day 2 Trial 1 12.82 ± 0.94
Day 2 Trial 2 9.92 ± 0.79	Day 2 Trial 2 12.77 ± 1.05
Day 3 Trial 1 9.59 ± 0.79	Day 3 Trial 1 12.49 ± 0.97
Day 3 Trial 2 9.61 ± 0.76	Day 3 Trial 2 12.54 ± 0.92
Intraclass Reliability = 0.92, $p \leq 0.01$	Intraclass Reliability = 0.85, $p \leq 0.01$
Coefficient of Variation = 3.7 ± 3.2%	Coefficient of Variation = 5.3 ± 2.9%
Day Effect = $p \leq 0.03$	Day Effect = $p \leq 0.01$
Trial Effect = Non-Significant	Trial Effect = Non-Significant
Day x Trial Effect = Non-Significant	Day x Trial Effect = Non-Significant
N19/N20 (msec)	**P22** (msec)
Day 1 Trial 1 18.30 ± 1.23	Day 1 Trial 1 22.45 ± 1.75
Day 1 Trial 2 18.35 ± 1.46	Day 1 Trial 2 22.42 ± 1.78
Day 2 Trial 1 18.70 ± 1.22	Day 2 Trial 1 22.41 ± 1.23
Day 2 Trial 2 18.92 ± 1.29	Day 2 Trial 2 22.71 ± 1.47
Day 3 Trial 1 18.09 ± 1.45	Day 3 Trial 1 22.16 ± 1.39
Day 3 Trial 2 18.47 ± 1.52	Day 3 Trial 2 22.25 ± 1.58
Intraclass Reliability = 0.93, $p \leq 0.01$	Intraclass Reliability = 0.92, $p \leq 0.01$
Coefficient of Variation = 18.5 ± 4.8%	Coefficient of Variation = 3.5 ± 2.1%
Day Effect = $p \leq 0.01$	Day Effect = Non-Significant
Trial Effect = Non-Significant	Trial Effect = Non-Significant
Day x Trial Effect = Non-Significant	Day x Trial Effect = Non-Significant

Table 2. Amplitude measures (Mean ± SD) by day and trial with consistency (Intraclass *R*) and stability (ANOVA) of measures and the coefficient of variation.

Base to Peak N9 (μV)	**Base to Peak N13** (μV)
Day 1 Trial 1 0.92 ± 0.67 Day 1 Trial 2 1.03 ± 0.65 Day 2 Trial 1 1.16 ± 0.74 Day 2 Trial 2 1.17 ± 0.98 Day 3 Trial 1 1.18 ± 0.84 Day 3 Trial 2 1.15 ± 0.89 Intraclass Reliability = 0.77, $p \leq 0.01$ Coefficient of Variation = 53.6 ± 29.9% Day Effect = Non-Significant Trial Effect = Non-Significant Day x Trial Effect = Non-Significant	Day 1 Trial 1 0.91 ± 0.55 Day 1 Trial 2 1.09 ± 0.62 Day 2 Trial 1 1.14 ± 0.58 Day 2 Trial 2 1.42 ± 1.04 Day 3 Trial 1 1.15 ± 0.63 Day 3 Trial 2 1.02 ± 0.61 Intraclass Reliability = 0.72, $p \leq 0.01$ Coefficient of Variation = 47.4 ± 19.9% Day Effect = Non-Significant Trial Effect = $p \leq 0.05$ Day x Trial Effect = Non-Significant
Base to Peak N19/N20 (μV)	**Peak to Peak N19/N20 to P22** (μV)
Day 1 Trial 1 1.95 ± 1.05 Day 1 Trial 2 2.05 ± 1.31 Day 2 Trial 1 2.24 ± 1.05 Day 2 Trial 2 2.67 ± 1.65 Day 3 Trial 1 2.11 ± 0.85 Day 3 Trial 2 2.00 ± 0.72 Intraclass Reliability = 0.76, $p \leq 0.01$ Coefficient of Variation = 36.1 ± 13.8% Day Effect = Non-Significant Trial Effect = Non-Significant Day x Trial Effect = Non-Significant	Day 1 Trial 1 2.10 ± 1.25 Day 1 Trial 2 2.13 ± 1.26 Day 2 Trial 1 2.16 ± 1.20 Day 2 Trial 2 1.88 ± 1.30 Day 3 Trial 1 2.23 ± 0.95 Day 3 Trial 2 1.85 ± 0.96 Intraclass Reliability = 0.88, $p \leq 0.01$ Coefficient of Variation = 40.7 ± 33.2% Day Effect = Non-Significant Trial Effect = Non-Significant Day x Trial Effect = Non-Significant

Standing height of the individual was significantly correlated with all latency (Table 3) and all amplitude (Tables 4) measures except for the N9 amplitude. Age was not correlated with any latency or amplitude measure. Significant differences between men and women existed for most of the latency and amplitude measures (Table 5). Overall study normative values are shown in Table 6.

Table 3. Correlation of volunteer standing height and waveform latencies.

Latency Waveforms	**N9**	**N13**	**N19/N20**	**P22**
R	0.66	0.85	0.77	0.79
***p* value**	0.01	0.0005	0.001	0.001

Table 4. Correlation of volunteer standing height and waveform amplitudes.

Amplitude Waveforms	**N9 Baseline-Peak**	**N13 Baseline-Peak**	**N19/N20 Baseline-Peak**	**N19/N20-P22 Peak-Peak**
R	-0.24	0.85	0.77	0.79
***p* value**	NS	0.0005	0.001	0.001

Table 5. Somatosensory median nerve evoked potential values by gender with significant differences noted.

	MEN Mean ± S.D.	**WOMEN Mean ± S.D.**	**Significance**
Latencies	**(msec)**	**(msec)**	
N9	9.78 ± 0.85	9.37 ± 0.62	NS
N13	13.19 ± 0.66	12.09 ± 0.59	0.001
N19/N20	18.95 ± 1.02	17.58 ± 0.68	0.002
P22	22.74 ± 1.15	21.54 ± 1.26	0.03
Amplitudes	**(μV)**	**(μV)**	
N9	0.93 ± 0.54	2.04 ± 1.52	0.02
N13	0.94 ± 0.40	1.36 ± 0.31	0.01
N19/N20	1.97 ± 0.79	2.53 ± 0.46	NS
N19/N20-P22	1.70 ± 0.89	2.52 ± 0.68	0.03

Table 6. Somatosensory median nerve evoked potential normative values (Mean ± SD) for USARIEM Evoked Potential Laboratory compared to other laboratories.

LABORATORY **Sample Size (*n*)**	**USARIEM** (*n* = 21)	**Ref. # (4)** (*n* = 20)	**Ref. # (5)** (*n* = 16)	**Ref. # (11)** (*n* = 53)	**Ref. # (18)** (*n*=35)	**Ref. # (25)** (*n* = 23)
Latencies (msec)						
N9	9.67± 0.80	9.67± 0.73	9.6 ± 0.7	9.91± 0.72	9.24 ± 0.62	10.0 ± 0.6
N13	12.81 ± 0.87	13.12 ± 0.88	13.2 ± 0.8	13.24 ± 0.92	12.78 ± 0.55	13.2 ± 0.7
N19/N20	18.43 ± 1.18	18.79 ± 1.08	18.9 ± 1.0	19.06 ± 1.01	18.43 ± 0.65	19.1 ± 0.8
P22	22.31 ± 1.39	22.94 ± 2.05				
Amplitudes (μV)						
N9	1.20 ± 0.61	3.36 ± 2.50	5.4 ± 2.5			4.14 ± 1.90
N13	1.15 ± 0.42	0.88 ± 0.44	2.9 ± 1.3			1.73 ± 1.10
N19/N20	2.23 ± 0.75	2.22 ± 1.07	2.8 ± 1.6			3.25 ± 2.16
N19/N20-P22	2.08 ± 0.86	1.79 ± 0.97				

DISCUSSION

Normative values and reliability measures of the data obtained from our laboratory were assessed. Our sample somatosensory evoked potential (SEP) mean latencies and their ranges are similar to laboratories that have published normative values (4, 5, 11, 18, 25) for right arm median nerve stimulation with similar electrode montages (Table 6). The variability observed between laboratories could be considered small and within acceptable levels (11, 23). The various waveform latencies are considered normal as they fall within the standard used by most laboratories ($\pm$ 2.5 SD) or if 98% of a population is included (6). Reliability estimates using intraclass *R* values for latencies between 0.85 and 0.93 and amplitudes of between 0.72 and 0.88 compared favorably with the similar intraclass *R* values obtained by others, 0.63 to 0.82 (21) and 0.82 to 0.93 (4) for latencies and 0.26 to 0.55 (4) for amplitudes. The N19/N20 component was the most variable in our laboratory assessment. The N19/N20 component is generated in the parietal cortex or thalamus regions of the brain (7, 23). This variability may have been due to the level of subject arousal. Emerson et al. (12) demonstrated that while other short latency potentials are unaffected by level of arousal or sleep, the N19/N20 waveform was prolonged if volunteers fell asleep while being tested. In our study, volunteers were instructed to close their eyes and relax, but not to go to sleep. We do not know how many volunteers may have drifted to sleep for short periods of time during data collection, possibly affecting the N19/N20 latency. It is important to ensure volunteers are relaxed and as free from movement as possible to minimize artifacts, but it may be equally important to maintain wakefulness if comparisons are going to be made across experimental conditions.

Examination of the stability (ANOVA analyses) of measures across trials showed that latencies (N9, N13, N19/20, P22) and amplitudes (N9, N13, N19/20, N19/20-P22) showed some day and trial effects that were greater than those shown previously using a repeated measures ANOVA (4). One possible reason may have been that electrode placement varied somewhat between days as evidenced by the day effects for the N9, N13, and N19/20 latencies while no trial or day by trial effects existed. However, the consistency of measures was high as evidenced by the intraclass reliability estimates and the low CVs (~ 5%) associated with the N9, N13, and P22 latency measures. The CV of N19/20 was slightly higher, and was possibly a result of differences in arousal level. Overall, median nerve latencies obtained in this study were highly reliable.

Amplitude measurements obtained in our laboratory were more reliable than some laboratories (4, 5, 25) but were too variable to be used reliably as a single diagnostic measure (5, 7, 10, 11, 22, 23, 25). Because measures of amplitude were more variable in this study as well as others, amplitude is not customarily used except when comparing marked differences between the two sides of the body (7). A potential difficulty in obtaining reliable amplitude measurements is that there are inherent variations in normal waveforms especially in the cortical measurements due to anatomical differences in the brain and the head in general (14, 22). Another difficulty is that amplitude does not follow a Gaussian distribution in the normal population (5, 22).

Because amplitude measurements do not follow normal distributions, it creates difficulty in statistical analysis.

Volunteer age within the range used in this study, was not correlated to any of the waveform latencies or amplitudes, corroborating previous research (1, 2, 19). Standing height has been demonstrated to be significantly correlated with SEP peak latencies (1, 2, 8, 9, 19). Standing height was similarly positively correlated with latencies and amplitudes in our measurements. Correlations exist in latency measures because the somatosensory pathways are longer in taller (i.e., longer limbed) individuals and hence the latency of the SEP will be longer because the signal has to travel further from the stimulus site to the recording site (5). Akyüz et al. (1) report that standing height as a covariate is the most reliable measurement of nerve conduction time because other measurements such as limb length have larger measurement errors. Normal latencies in tall individuals may be interpreted as abnormally long latencies in short individuals if they were not adjusted for height (24), again showing the importance of knowing standing height when interpreting the data. Correlation between height and waveform amplitude has not been cited previously and an explanation for the significant correlations in this study are unclear. It appears methodologies that use the individual as their own control are preferable because treatments are then not influenced by standing height.

Men had longer mean latency times than women for the N9, N13, and N19/N20 waveforms, which is similar to previous findings (1,19). Akyüz et al. (1) found that after controlling for standing height, no gender differences existed for the N9 and N13 waveforms, but that men had longer latencies than women for the N19/N20 waveform. Because standing height measurements were not made on most of the women in our study, gender differences associated with standing height could neither be confirmed nor disproved. However, the data of the two women that did have standing height measurements were similar to those of the men, (i.e., they were not outliers) for all latency and amplitude measures when dividing the latency or amplitude by standing height and examined as Box and Whisker plots.

CONCLUSIONS

The analyses demonstrated that median nerve SEP latencies were reliable and amplitudes measures were not reliable. Normative values for median nerve SEPs are presented for the USARIEM EP Laboratory. Gender differences were evident with women having shorter latencies and larger amplitudes than men. Standing height should be measured or considered when assessing median nerve SEP latency differences due to experimental treatments or neurological disorders. These normative values are consistent with those obtained from other laboratories published in the literature. Since these data demonstrate that the techniques employed in this study produce valid and reliable measurements, future studies using median nerve SEPs at

USARIEM should now use the values published in this report as the normative values for comparative purposes.

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